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Comparison of Mechanical Properties of Mortar Containing Industrial Byproduct

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Abstract

The use of industrial by-products and wastes in construction industry solves two fold problem of the waste by-product disposal and development of sustainable building material. The disposal of PET bottles and steel chip powder or SCP (major by-product of steel and fabrication units) is a major problem as they are non biodegradable in nature. So these by-products (PET and SCP) pose an environmental issue and its usage in construction industry can be a major achievement. This paper explores the possibility of using shredded PET bottles and steel chip powder (SCP) in mortar. The effect of adding PET and SCP in the compressive strength of the mortar were experimental investigated the mortar proportion of 1:3 with replacement percentage of 2, 4, 6 and 8 with keeping water-cement ratio constant. The strengths of specimen were recorded for 28 days and 7 days and results showed that the strength decreased drastically when percentage replacement was increased and it was concluded that 6 percentage replacements is optimum replacement. Also it was observed that workability decreased as percentage replacement increased.

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Keywords: SCP, Suistainable , PET, mortar, alternate construction material

1. Introduction

Vast amounts of industrial waste or industrial byproducts are produced every year in the world. And its proper disposal is a serious problem in many countries. Heavy raw materials such as cast iron, steel,

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aluminum, steel chips from steel industries are the major byproducts of the metal industries. Plastics are widely used due to their adaptability, lightness, chemical resistance etc and contribute most to solid waste volume among which Polyethylene Terephthalate(in form of PET bottles) is the major culprit. The both by-products are either stored or land filled without knowing detrimental effects on the environment.But, with the increasing concerns about environment and natural resources consumption, limited landfill space and rapidly increasing disposal cost, the use or recycling of these byproducts has become an interesting research topic worldwide. The use of industrial byproducts in concrete is becoming common due to the advantages it offers in economical, technical and environmental aspects.The usage of industrial wastes and byproducts in construction entity lowers the direct and indirect costs [1] with environmental advantages over conventional materials with acceptable performance profile in terms of durability, safety and strength. Examples of byproducts or wastes currently in study for usage in construction entities are Fly Ash [2], Silica Fume [2], pulverized fuel ash [2], Granulated blast furnace ash [2], scrap tyres [1], shredded PET bottles and foundry sand. Steel and PET by-products were chosen for this research because (1)SCP have strong metallic material having same material properties to that of concrete and due to light weight of PET dead load get reduced (2)an easily available and cheap by-product. Also replacing cement which cost about 20 to 25 % in concrete in overall building budget may prove economical for projects involving low cost housing projects.

2. Literature Review

Not much work has been registered on the use of metallurgical by product such as steel chip powder and in shredded PET in concrete or mortar as such. Though some researchers have reported on this area such as Khattib and ellies [3] who partially replaced sand with 3 types foundry sand and studied the change in properties of concrete and concluded that Strength of concrete was decreased due to increasing percentage of foundry sand among other such conclusions. Naik at el. [5] studied the use of high volume fly ash, bottom ash and waste foundry sand in wet cast concrete brick and paving stone and showed that Development of strength was age dependent as The compressive strength of paving stone continued to increase with age but fell short of ASTM C936 requirement (min 15 MPa). Etxeberria at el. [6] studied the properties of concrete with chemical foundry sand (QFS), green foundry sand (GFS) as a partial replacement for fine aggregate and blast furnace slag (BFS) as a partial replacement of coarse aggregate and concluded that concrete made with chemical and green foundry sand developed more compressive strength, tensile strength and modulus of elasticity than regular concrete when casted with high water cement ratio and suffered same change in length as regular concrete. Also, concrete with chemical foundry sand developed highest workability, but use of slag as coarse aggregate more than 50% decreased the workability of concrete .Choi et al. [7] researched WPLA microstructure which is obtained from waste PET bottles in the study where WPLA was made from the waste PET granules and GBFS on the surface of aggregates. And it was shown that the specific gravity and the bulk density of WPLA was lower than the natural aggregate by 50% due to which The compressive strength and the density of WPLA concrete decreased as the replacement ratio and w/c ratio increased(due to expanded transition layer). Akcaozoglu et al. [9] studied the strength properties of two group of mortars which waste PET lightweight aggregates (WPLA) have been used as partial and full substitutes for sand. As a result of the study, the compressive strengths of mortar specimens were over 20 MPa, flexural–tensile strengths were over 4.7 MPa. The authors concluded that, the specimens can be put into structural lightweight concrete category in terms of unit weight and strength properties.

3. Materials Used

3.1. Cement

Ordinary Portland cement (Type 1) conforming to IS: 12269 -1987 was used. The physical and chemical properties of cement are presented in Table 1.

3.2. Aggregate

Normal weight natural sand having a maximum particle size of 4.75 mm and specific gravity 2.6 was used as fine aggregate. Properties of sand are reported in Table 2 and its size distribution is according to requirements of ASTM C33/C33M-08.

3.3. Steel Chips (Powdered)

Steel is an alloy of chiefly iron with carbon, manganese, phosphorus, sulfur, silicon and traces of oxygen, nitrogen and aluminum. When carbon is primary alloying element, its content in the steel is between 0.002% and 2.1% by weight. The steel byproduct comes mainly in the form of powder from the casting and lathing industry. It has maximum particle size of 4.00 mm.

3.4. Pet Fibers (Shredded)

PET is basically is a thermo plastic resin composed of phthalates.PET was shredded in different aspect ratios rather than using in straight strips like cramped, twisted or embossed form to improve bond strength. PET byproduct was added at different percentages by weight of fine aggregate.

Table 1. The chemical analysis and physical properties of the cement

	Particular	Typical Range	Requirement of IS: 12269-1987
	Chemical Properties		
1	Lime saturation factor(LSF)	0.90-0.92	0.66 to 1.02
2	Alumina to that of Iron oxide ratio%(A\F)	1.20-1.40	0.66 min
3	Insoluble residue(% by mass)	1.0-1.20	3.00 max
4.	Magnesium oxide(% by mass)	3.0-3.50	6.00 max
5.	Sulphuric Anhydride(% by mass)	1.80-2.00	3.00 max
6.	Total loss on ignition(% by mass)	1.0-1.20	4.00 max
7.	Total chloride(% by mass)	0.010-0.014	0.10 max (for N.C.)* 0.05 max (for P.C.)*
	PHYSICAL PROPERTIES		
1.	Fineness(M2/kg)	320-340	225 min
2.	Setting Time(minutes)		
	Initial	110-120	30 min
	Final	150-180	600 max
3.	Expansion		
	Le Chatelier (mm)	2.00	10.00 max
	Auto clave (%)	0.14	0.8 max
4.	Compressive Strength(Mpa)		
	3 Days	40.4	27 min
	7 Days	49.6	37 min
	28 Days	due	53 min

Table 2. Grading and properties of fine aggregate

Sieve Size(mm)	Percentage Passing	Limits of specifications ASTM C33/C33M-08
9.5	100	100
4.75	98	95-100
2.36	92	80-100
1.18	84	50-85
0.60	57	25-60
0.30	23	5-30
0.15	3	0-10
Property	Result	
Bulk Specific Gravity	2.62	
Absorption (%)	0.70	
Sulfate content as SO_3(%)	0.08	

4. Mortar Mix Proportion

The proportion of 1:3 was taken with corresponding water to cement ratio (w/c) of 0.4 which was kept constant during the whole experimental program and with a targeted 7-days and 28-days compressive strength. The minimum compressive strength of the paving stone is 15 Mpa as per ASTM C936 [5, 8].The mixes were prepared by adding steel byproduct and PET by-product at 2%, 4%, 6% and 8% weight of sand. The mortar mix design is presented in Table 3 and Table 4.Laboratory mechanical mixing was done for all mortar mixes.

Table 3. Mix proportion of the mortar of SCP

Sl no	Materials	1:3			
		2%	4%	6%	8%
1	Fine Aggregate(kg/m^3)	1996.79	1934.01	1910.31	1866.75
2	Cement(kg/m^3)	679.05	678.41	677.13	676.48
3	Net Water (kg/m^3)	271.62	271.36	270.99	270.62
4	Water to Cement Ratio	0.4	0.4	0.4	0.4
5	Steel chip powder(kg/m^3)	40.74	81.35	121.90	162.37

Table 4. Mix proportion of the mortar of PET

Si no	Materials	1:3			
		2%	4%	6%	8%
1	Fine Aggregate(kg/m^3)	1973.09	1907.28	1885.9	1778.98
2	Cement(kg/m^3)	670.72	661.75	654.70	644.44
3	Net Water (kg/m^3)	268.41	264.89	261.88	257.78
4	Water to Cement Ratio	0.4	0.4	0.4	0.4
5	PET Shredded(kg/m^3)	40.23	79.46	117.87	154.73

5. Casting of Specimens

For the compression test pavement bricks were casted with the volume 1561 cm^3 and surface area 260.50

cm^2 from each mix. After casting all the test specimens were stored at room temperature and then de-molded after 24h, and placed into a water-curing tank until the time of testing. Compressive strength was performed for two specimens at 7 days and 28 days and average results are reported in this paper.

6. Hardened Mortar Properties

The proportion of 1:3 was considered and for each by-product and subsequent each percentage replacement, two bricks were casted for 7 days strength and two for 28 days strength and were tested in digital compression testing machine. The maximum load was recorded and compressive strength was calculated. Table 5 gives the average 7 days and 28 days compressive strength for tested specimens.

7. Results and Discussions

7.1. Workability

There was a small reduction in concrete workability which subsequently decreased with increased by-product percentage. This can be attributed to the presence of SCP and PET particles in the mortar mix, which led to the increase in the surface area (increased water demand) as compared to the conventional control mixes. Also, the added by-products are solid materials which lead to increase in internal frictional forces and possible local accumulation particularly in case of higher replacement percentages (8%) thereby decreasing its workability.

7.2. Results and Conclusion

Table 5: Compressive strength wrt to different replacement percentage

	STRENGTH(wrt PERCENTAGE REPLACEMENT OF by-product)(inMpa)							
PROPORTION	2%		4%		6%		8%	
	7 Days	28 Days	7 Days	28 Days	7 Days	28 Days	7Days	28 Days
1:3(PET)	44.5	65.08	43.16	63.07	36.79	54.32	30.52	31.87
1:3 (SCP)	52.2	76.64	51.8	75	50	72.6	49.2	73.57

The compressive strength results of mortar mixture with different percentages of PET and SCP replacement at ages 7 Days and 28 Days are presented in table 5. It was observed that the strength of mortar mixture decreased prominently after replacement percentage of 4 for 1:3 in case of PET. The compressive strength for 7 days was almost same up to 4 percent replacement and then decreased drastically and for 28 days it decreased gradually without much difference till 6 percentage replacements and then decreased drastically for 8 percent. In case of SCP the decrease was gradual in case of 7 days strength and in 28 days strength the fall of strength was rather steep from 4 % replacement to 6 % replacement as compared to other where fall was rather gradual.

The improved strength can be due to the effect of plastic fibers and steel chip powder in bridging micro cracking which slow down crack propagation. But, significant increase in the surface area of the PET fiber and SCP uses up much of cement paste for coating thus decreasing the cement for binding and thereby reducing strength. Also, the presence of uncoated PET fibers due to in adequate paste available creates macro or probably micro defects in the micro structure and reduces the internal stress transfer capacity of the fibers and matrix. So, it was concluded that the 6 % replacement of both the by-products by the weight of fine aggregate is optimum which can be used without compromising the strength much.

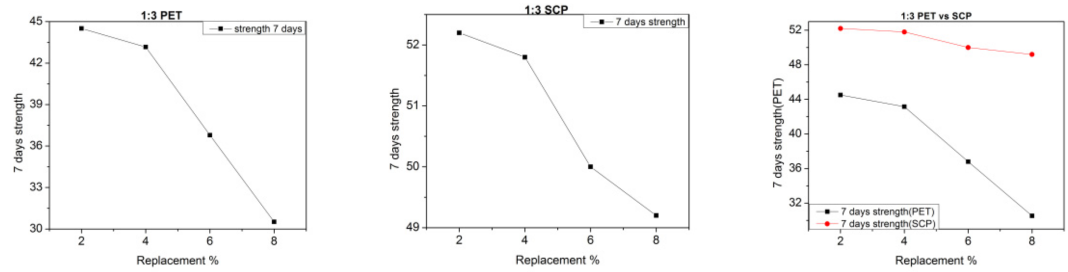

Fig. 1. (a) 7 day strength vs Replacement percentage (1:3 PET); (b) 7 day strength vs Replacement percentage (1:3 SCP); (c) 7 day strength vs Replacement percentage (1:3 PET vs SCP)

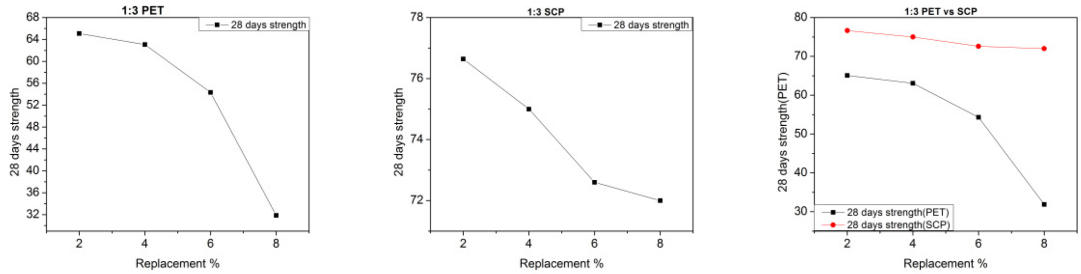

Fig. 2. (a) 28 day strength vs Replacement percentage (1:3 PET); (b) 28 day strength vs Replacement percentage (1:3 SCP); (c) 28 day strength vs Replacement percentage (1:3 PET vs SCP)

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